

Peter M. A. van Ooijen  
Gonda de Jonge  
Matthijs Oudkerk

## Coronary fly-through or virtual angiography using dual-source MDCT data

Received: 11 April 2007  
Revised: 23 April 2007  
Accepted: 27 April 2007  
Published online: 12 June 2007  
© Springer-Verlag 2007

This work was presented as posters at the NASCI 2006 and the ESCR 2006

P. M. A. van Ooijen (✉) · G. de Jonge · M. Oudkerk  
Department of Radiology, University Medical Center Groningen, University of Groningen,  
Hanzeplein 1,  
9700 RB Groningen, The Netherlands  
e-mail: p.m.a.van.ooijen@rad.umcg.nl  
Tel.: +31-50-3612286

**Abstract** Coronary fly-through or virtual angiography (VA) has been studied ever since its invention in 2000. However, application was limited because it requires an optimal computed tomography (CT) scan and time-consuming post-processing. Recent advances in post-processing software facilitate easy construction of VA, but until now image quality was insufficient in most patients. The introduction of dual-source multidetector CT (MDCT) could enable VA in all patients. Twenty patients were scanned using a dual-source MDCT (Definition, Siemens, Forchheim, Germany) using a standard coronary artery protocol. Post-processing was performed on an Aquarius Workstation (TeraRecon, San Mateo, Calif.). Length travelled per major branch was recorded in millimetres, together with the time required in minutes. VA could be performed in every patient for each of the major coronary arteries.

The mean (range) length of the automated fly-through was 80 (32–107) mm for the left anterior descending (LAD), 75 (21–116) mm for the left circumflex artery (LCx), and 109 (21–190) mm for the right coronary artery (RCA). Calcifications and stenoses were visualised, as well as most side branches. The mean time required was 3 min for LAD, 2.5 min for LCx, and 2 min for the RCA. Dual-source MDCT allows for high quality visualisation of the coronary arteries in every patient because scanning with this machine is independent of the heart rate. This is clearly shown by the successful VA in all patients. Potential clinical value of VA should be determined in the near future.

**Keywords** Virtual angiography · Coronary arteries · Coronary fly-through · Post-processing · Dual-source CT

### Introduction

Coronary fly-through or virtual angiography (VA) using various generations of computed tomography (CT) devices has been reported in a number of publications since its first mention in 2000 [1–3]. Main reason for the minimal research on this topic was the limited application because of the requirements for an optimal CT scan and time consuming post-processing. Recent advances in post-processing software facilitate easy construction of VA, but until now image quality of coronary CT was insufficient in most patients. The

introduction of dual-source multidetector CT (MDCT) has shown a more stable quality of data in all patients because of higher temporal resolutions, which could prove to enable VA in all patients and allow investigation of the clinical value of this visualisation technique [4–6].

### Materials and methods

Twenty patients (13 male, mean age  $60 \pm 13$  years old) were selected at random from patients scanned for coronary

artery disease using a standard coronary artery protocol on a dual source MDCT (Definition, Siemens, Forchheim, Germany).

Post-processing was performed on an Aquarius Workstation (TeraRecon, San Mateo, Calif.). The software allows an automatic vessel fly-through, which provides inside front and rear views, together with a view of the path and location on the surface of the heart (Fig. 1). Besides this, three multiplanar reformation planes (sagittal, coronal and axial) are shown for the location of the camera. Length travelled per major branch was recorded in millimetres, together with the time required in minutes to perform the evaluation per major branch. Ostia of side branches were visualised, but no fly-through of those side branches was performed.

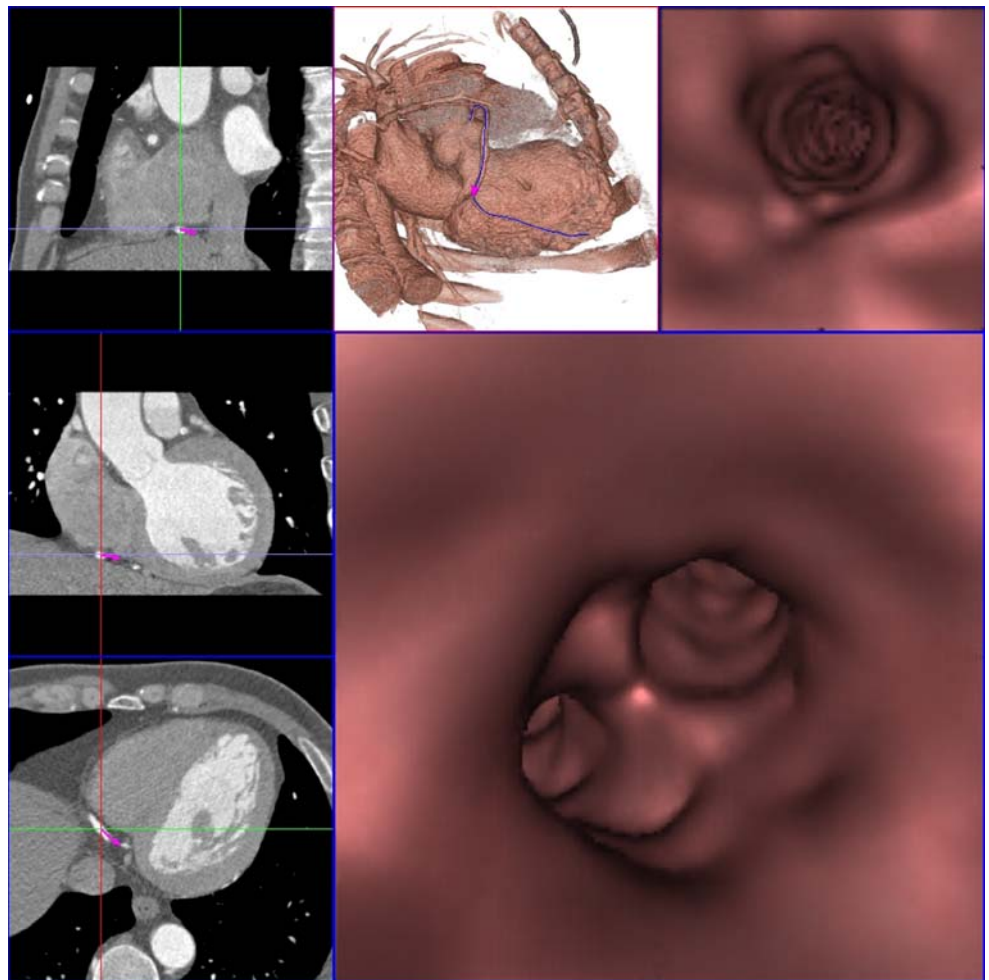
## Results

VA could be performed semi-automatically with minor user interaction in every patient for each of the major coronary arteries using dual-source CT (DSCT).

The mean (range) length of the automated fly-through was 80 (32–107) mm for the left anterior descending (LAD), 75 (21–116) mm for the left circumflex artery (LCx), and 109 (21–190) mm for the RCA.

Calcifications were clearly visualised as white structures floating inside the lumen. Stenoses were visualised when present by indentations of the lumen wall (Fig. 2). Visibility of the actual size of the stent lumen was still limited, but fly-through was possible in the stents we found (Fig. 3).

**Fig. 1** Large trajectory visualisation of the right coronary artery (RCA)



The major side branches of the main coronary arteries could be detected during the fly-through (Fig. 4). No fly-through was performed through those side branches.

The mean time required was 3 min for LAD, 2.5 min for LCx, and 2 min for the RCA.

## Discussion

The introduction of DSCT enables 100% visualisation of all major arteries and thus demonstrates a major gain in image quality compared with electron beam CT (EBCT) and MDCT, with only 76% and 84% assessable, respectively [3].

Furthermore, the time required for processing the data decreased to about 2.5 min compared with the 6–13 min required in 2002 (Table 1). Notice that the times shown in the table for EBCT and MDCT do not include the actual computing time, which could be hours with the hard- and software at that time. Currently, all computation and visualisation is in real time and thus included in the 2.5 min required for a coronary fly-through of a major branch using DSCT data.

Different artefacts still hamper the fly-through. First, non-optimal reconstruction will present itself as a sudden change in the form of the vessel wall. The effects are shown in Fig. 5, and it will be clear that these artefacts can be easily recognised because of the non-natural shape of the

wall. A more difficult artefact is caused by motion. Here, the artefact can be easily appreciated on the three-dimensional view, but in the fly-through it presents as an apparent stenosis (Fig. 6).

Finally, surgical clips in bypasses still pose a problem as already shown in an earlier publication using EBCT [1] (Fig. 7).

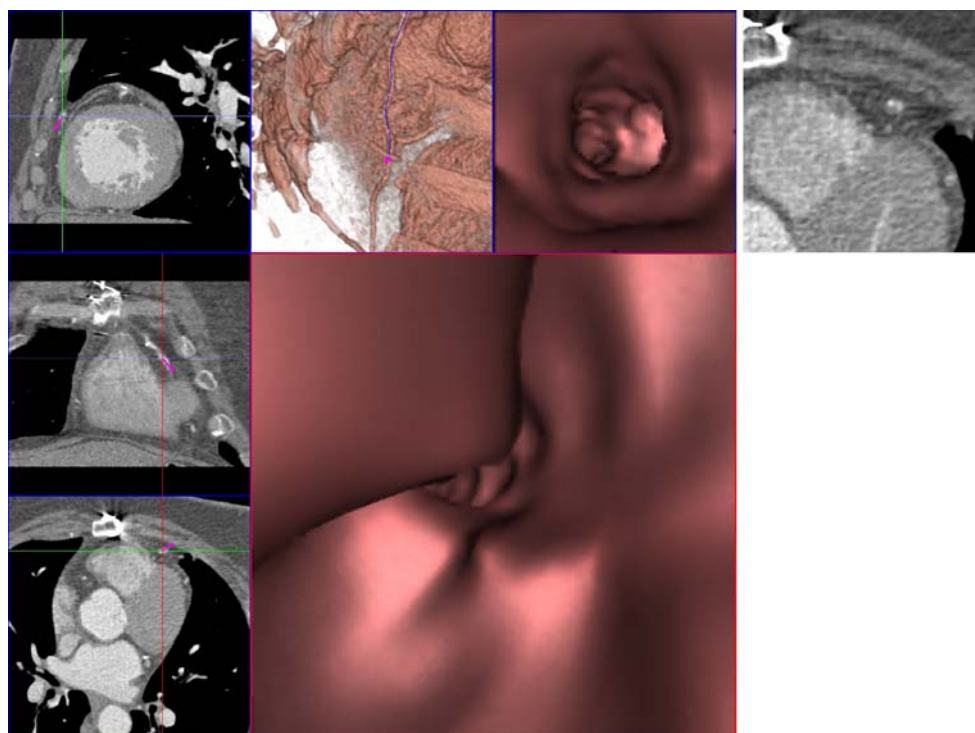
All three articles that (to our best knowledge) are available on this topic conclude with similar remarks [1–3]. They all state that the coronary fly-through or virtual coronary angiography (VCA) is a promising technique that, however, requires higher quality of the datasets and better image processing software.

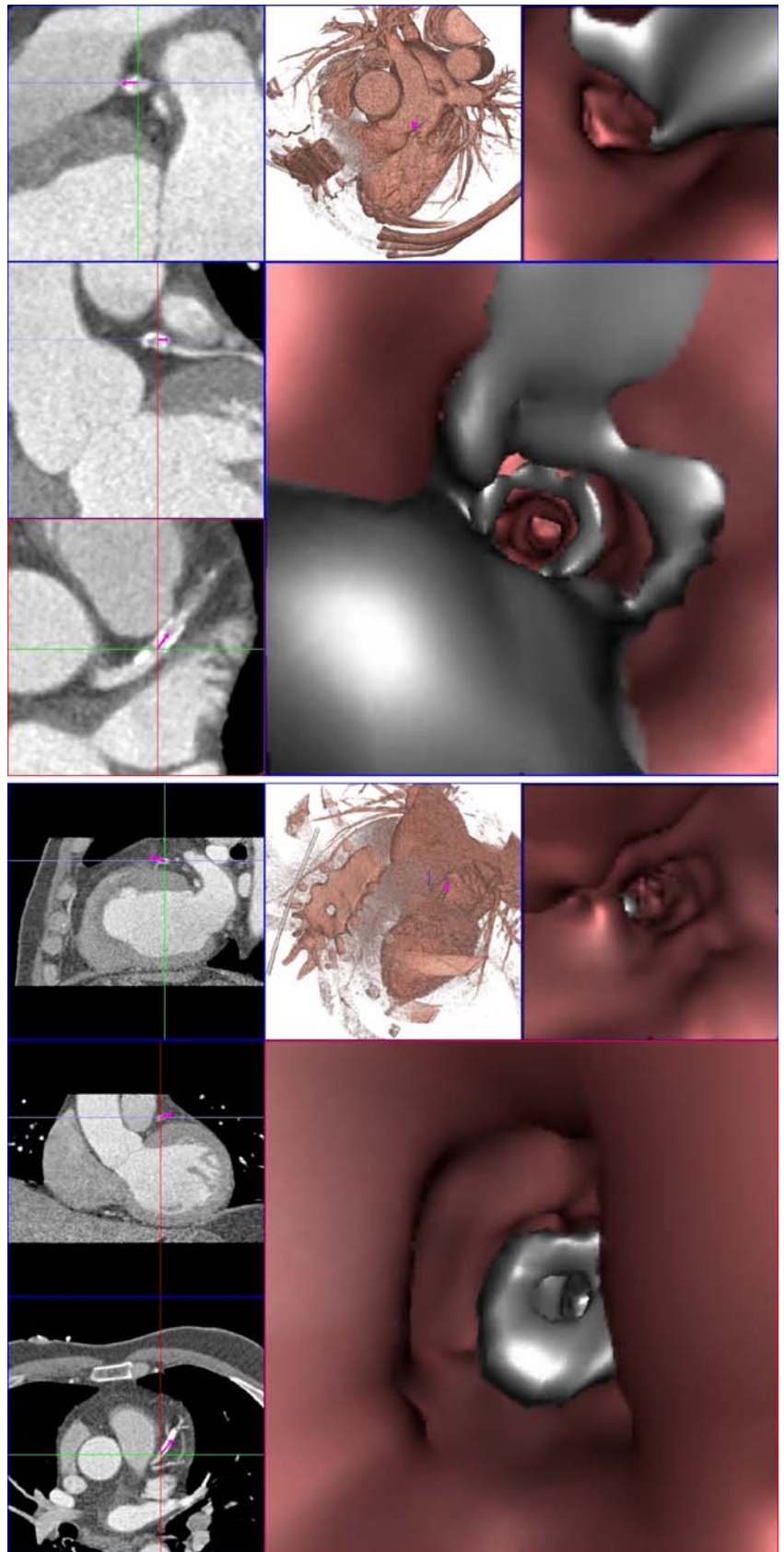
A shortcoming of our study was the lack of a “gold standard” to confirm the findings of the coronary fly-through.

## Conclusion

Dual-source MDCT provides a high quality visualisation of the coronary artery tree, independently of the heart rate. This is clearly shown by the successful VCA in all 20 patients in this study. With recent advancements of image processing software and CT acquisition techniques, the conditions have been met for providing the technical basis for the clinical validation of VCA and the potential clinical value of VCA should be determined in the near future.

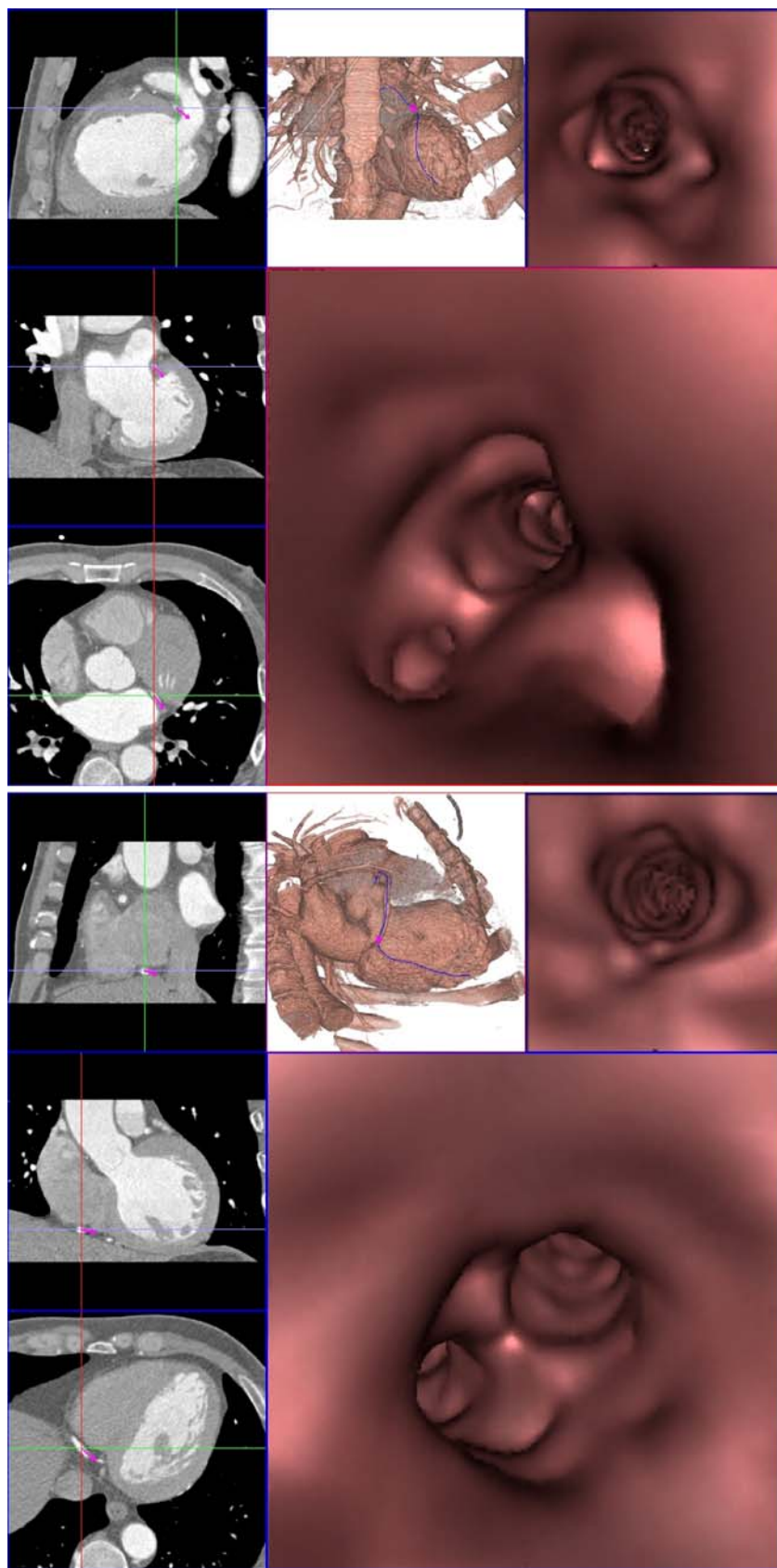
**Fig. 2** Visibility of a stenotic lesion



**Fig. 3** Stent visibility



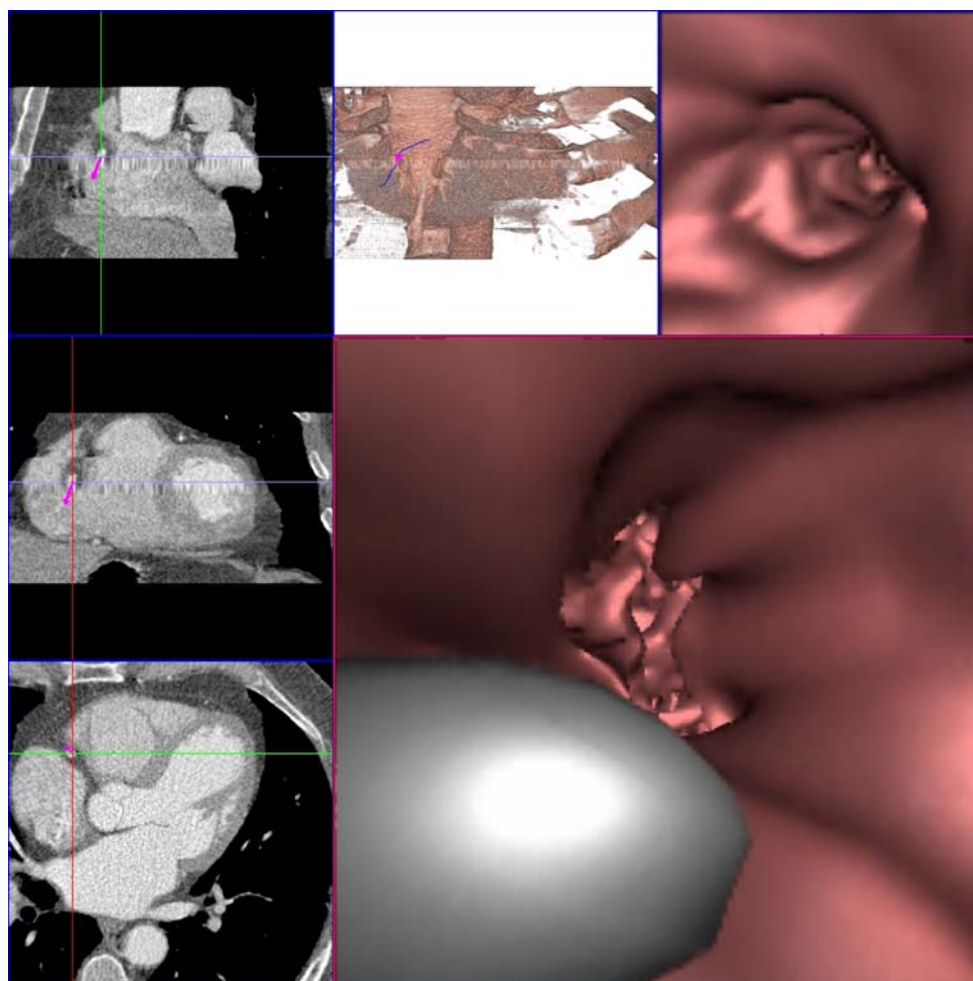
**Fig. 4** Visibility of major side branches



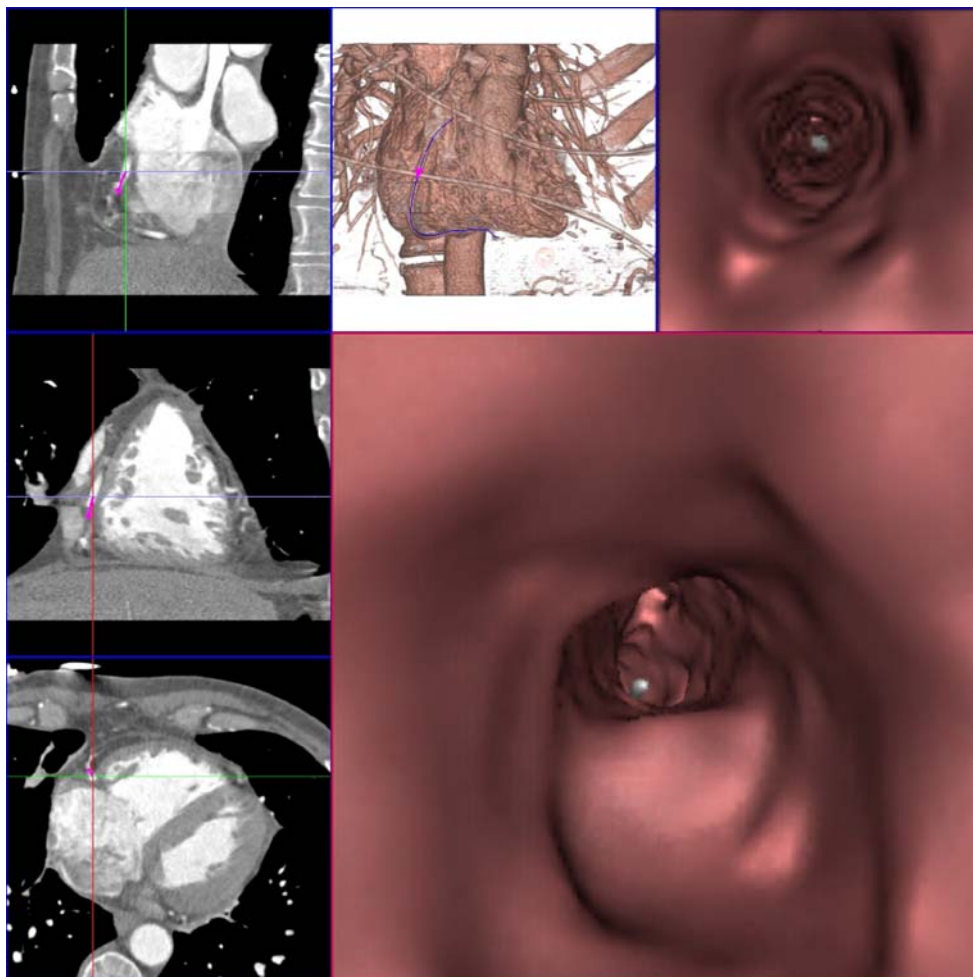
**Table 1** Results of an earlier study using EBCT and four-slice MDCT (4-MDCT) [3] in comparison with the DSCT results of the current study

	EBCT (2002)	4-MDCT (2002)	DSCT (2006)
<b>LAD</b>			
Percentage assessable	14/15 (93%)	14/15 (93%)	20/20 (100%)
Mean preparation time (min)	12	13	3
Mean number of key frames	13	16	<i>n.a.</i>
<b>LC</b>			
Percentage assessable	11/15 (73%)	10/15 (67%)	20/20 (100%)
Mean preparation time (min)	7	10	2.5
Mean number of key frames	9	13*	<i>n.a.</i>
<b>RCA</b>			
Percentage assessable	9/15 (60%)	14/15 (95%)	20/20 (100%)
Mean preparation time (min)	6	10	2
Mean number of key frames	8	14	<i>n.a.</i>
Total percentage assessable	34/45 (76%)	38/45 (84%)	60/60 (100%)

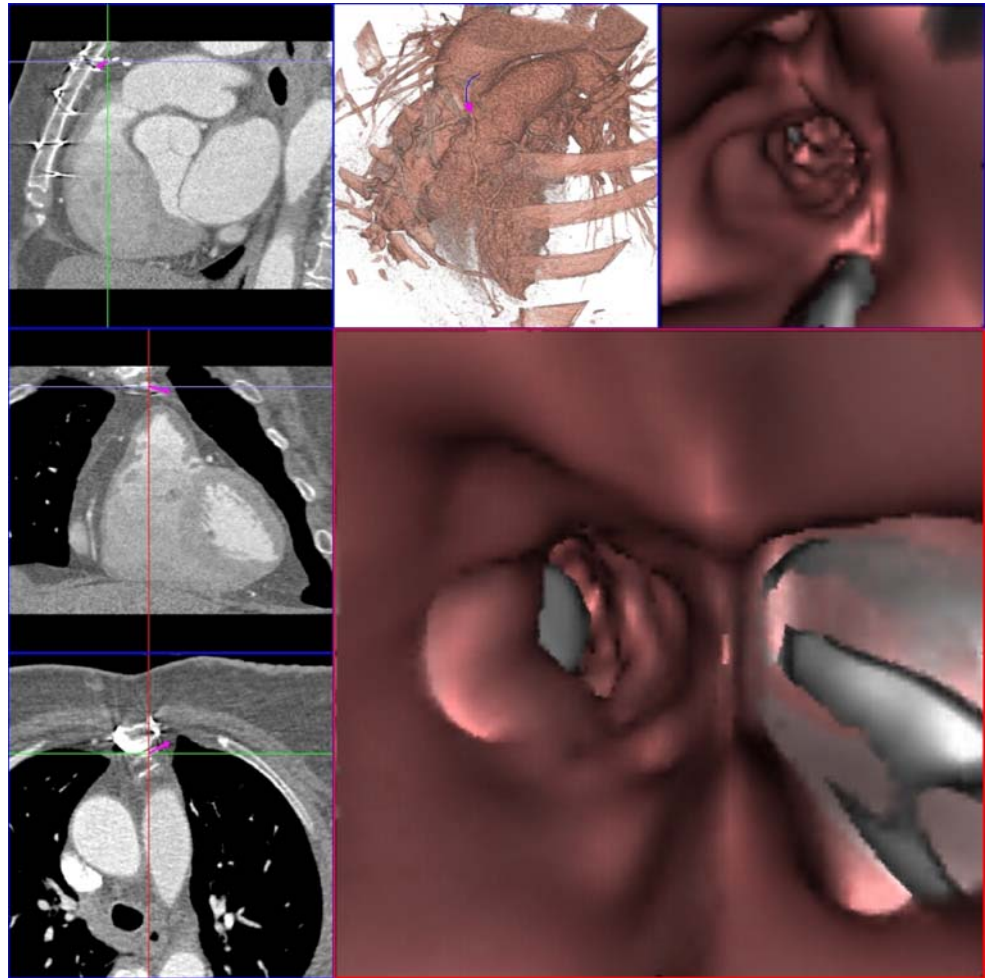
The number of key frames is no longer applicable (*n.a.*) for the current software tools that can perform the coronary fly-through in real time

**Fig. 5** Problems with artefacts in non-optimal reconstructed datasets

**Fig. 6** Problems with motion artefacts causing apparent stenoses



**Fig. 7** Visualisation is hampered by presence of surgical clips in a bypass graft



## References

1. van Ooijen PM, Oudkerk M, van Geuns RJ, Rensing BJ, de Feyter PJ (2000) Coronary artery fly-through using electron beam computed tomography. *Circulation* 102(1):E6–E10
2. Schroeder S, Kopp AF, Ohnesorge B, Loke-Gie H, Kuettner A, Baumbach A, Herdeg C, Claussen CD, Karsch KR (2002) Virtual coronary angiography using multislice computed tomography. *Heart* 87(3):205–209
3. van Ooijen PM, Nieman K, de Feyter PJ, Oudkerk M (2002) Noninvasive coronary angiography using electron beam computed tomography and multidetector computed tomography. *Am J Cardiol* 90(9):998–1002
4. Scheffel H, Alkadhi H, Plass A, Vachenaue R, Desbiolles L, Gaemperli O, Schepis T, Frauenfelder T, Schertler T, Husmann L, Grunenfelder J, Genoni M, Kaufmann PA, Marincek B, Leschka S (2006) Accuracy of dual-source CT coronary angiography: First experience in a high pre-test probability population without heart rate control. *Eur Radiol* 16(12):2739–2747
5. Johnson TR, Nikolaou K, Wintersperger BJ, Leber AW, von Ziegler F, Rist C, Buhmann S, Knez A, Reiser MF, Becker CR (2006) Dual-source CT cardiac imaging: initial experience. *Eur Radiol* 16(7):1409–1415
6. Flohr TG, McCollough CH, Bruder H, Petersilka M, Gruber K, Suss C, Grasruck M, Stierstorfer K, Krauss B, Raupach R, Primak AN, Kuttner A, Achenbach S, Becker C, Kopp A, Ohnesorge BM (2006) First performance evaluation of a dual-source CT (DSCT) system. *Eur Radiol* 16(2):256–268